US 20130149429A1

(19) **United States**

(12) **Patent Application Publication**

Romoda et al.

(10) **Pub. No.: US 2013/0149429 A1**

(43) **Pub. Date: Jun. 13, 2013**

(54) **SYSTEMS AND METHODS FOR MAKING GELATIN SHUNTS**

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(21) Appl. No.: **13/314,950**

(22) Filed: **Dec. 8, 2011**

Publication Classification

(51) **Int. Cl.**

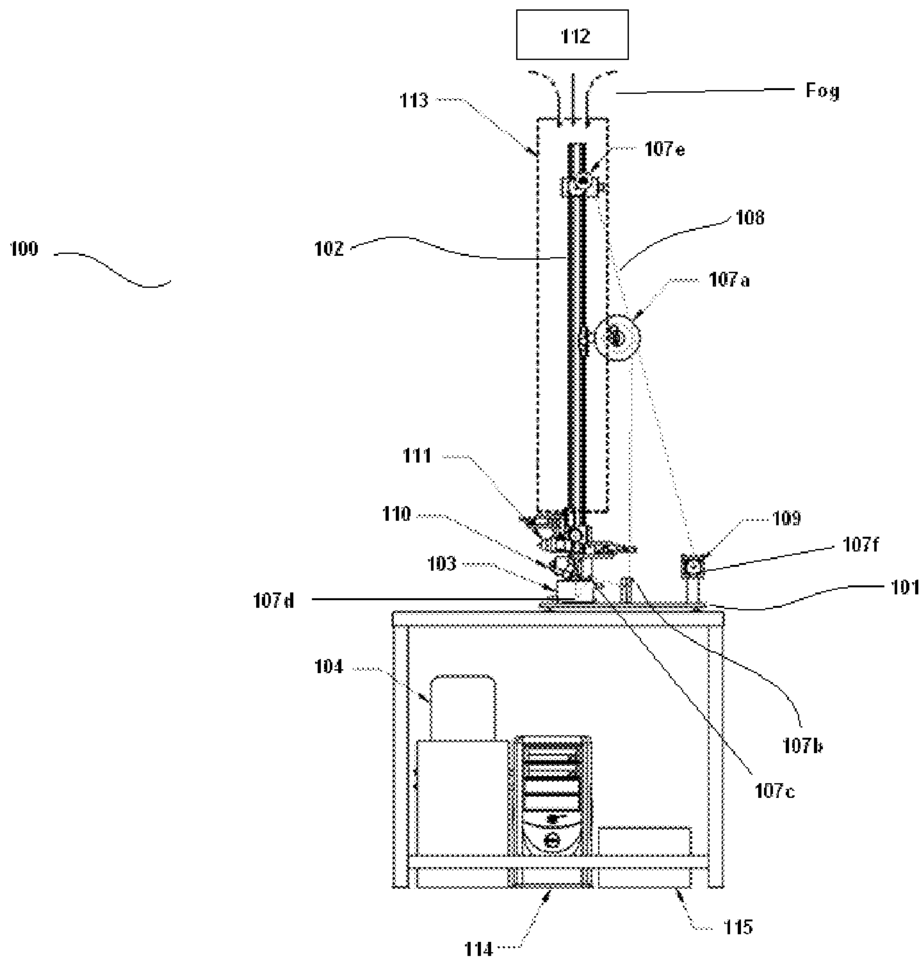
B05D 5/00	(2006.01)
B05C 3/02	(2006.01)
B05D 3/00	(2006.01)

(52) **U.S. Cl.**

USPC **427/2.3**; 118/420; 118/713

(57) **ABSTRACT**

The invention generally relates to systems and methods for making gelatin shunts. In certain embodiments, the invention provides methods that may involve moving a wire through a bath including a bottom layer of liquid gelatin and a top layer of water, thereby coating the wire with gelatin, moving the gelatin coated wire through an aperture, and drying the gelatin on the wire in a humidity controlled space, thereby manufacturing a gelatin shunt. In other embodiments, the invention provides systems that may include a motor, a wire operably coupled to the motor for movement of the wire, a temperature controllable bath, an aperture plate situated in a top portion of the bath, and an ultrasonic fogger, in which the system is configured such that the wire moves through the bath, through the aperture plate, and into the ultrasonic fogger.



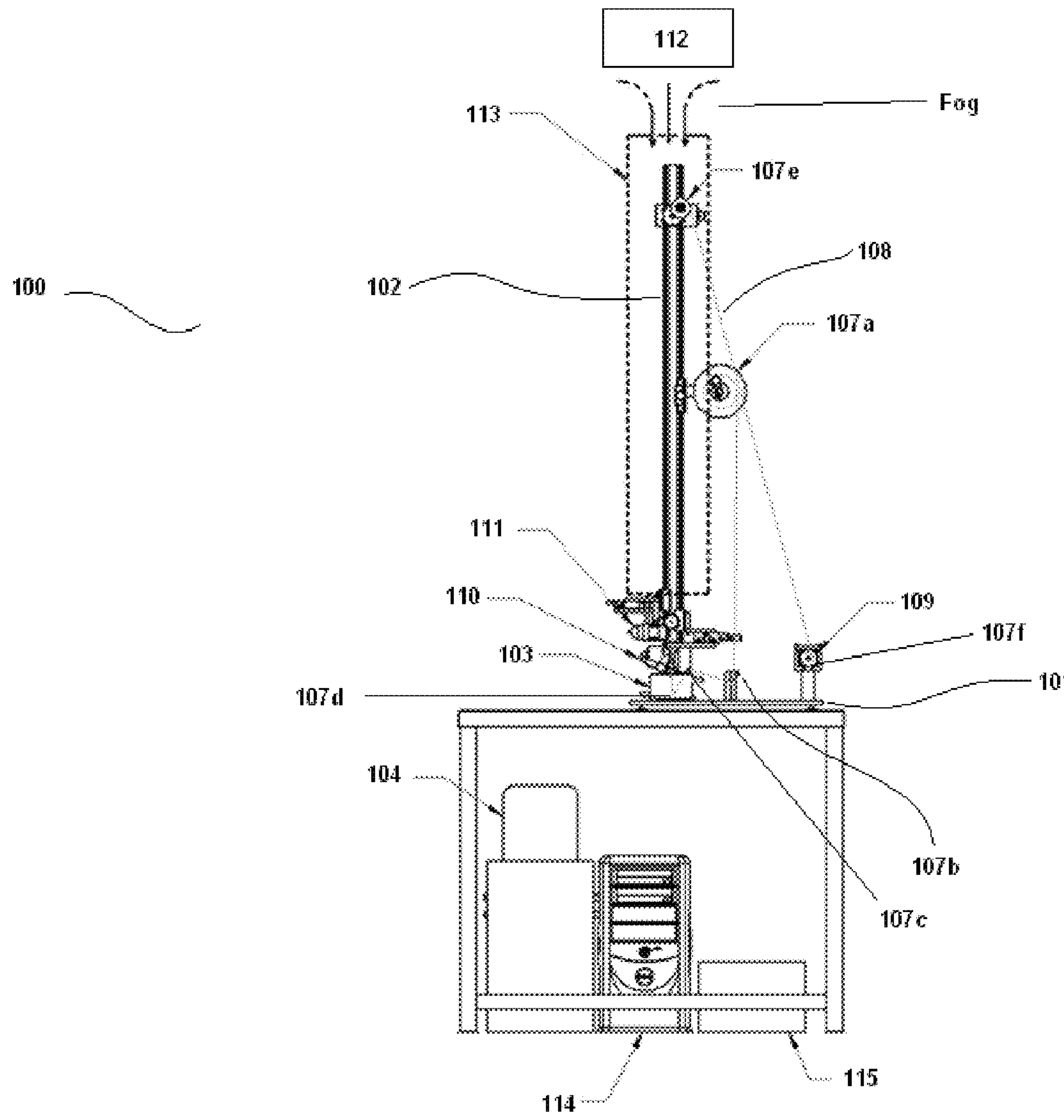
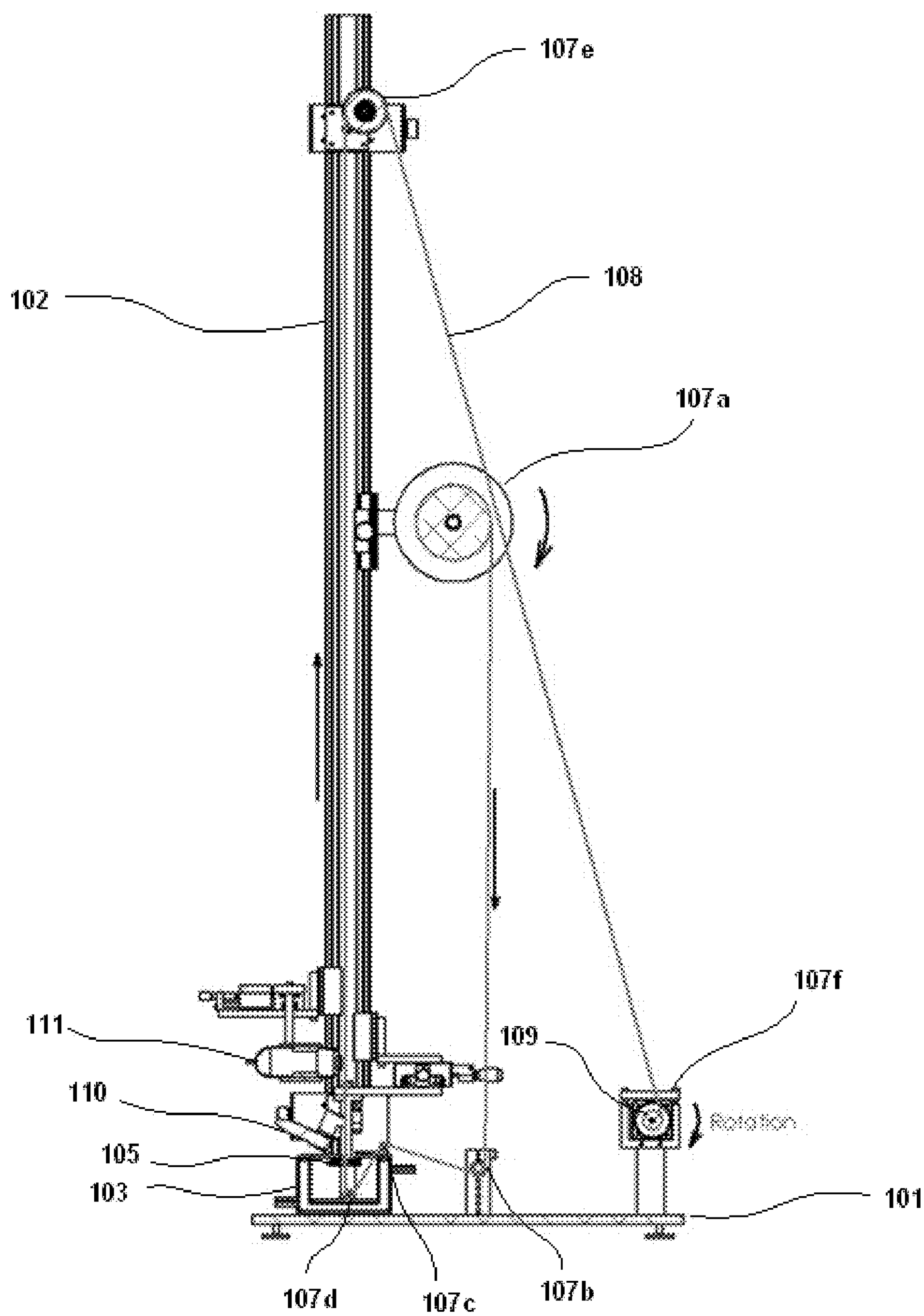

112
Fog
113
107e
108
100
102
107a
111
110
109
107f
103
101
107d
104
107b
107c
115
114

Figure 1


107e
108
102
107a
107f
111
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Rotation
110
105
103
101
107d
107c
107b

Figure 2

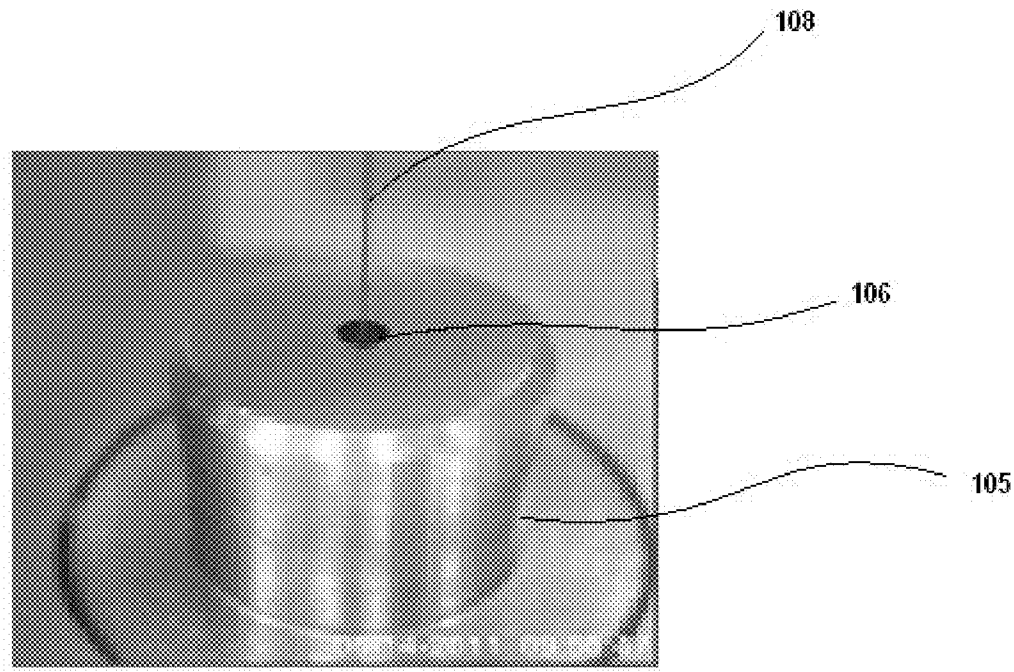


Figure 3

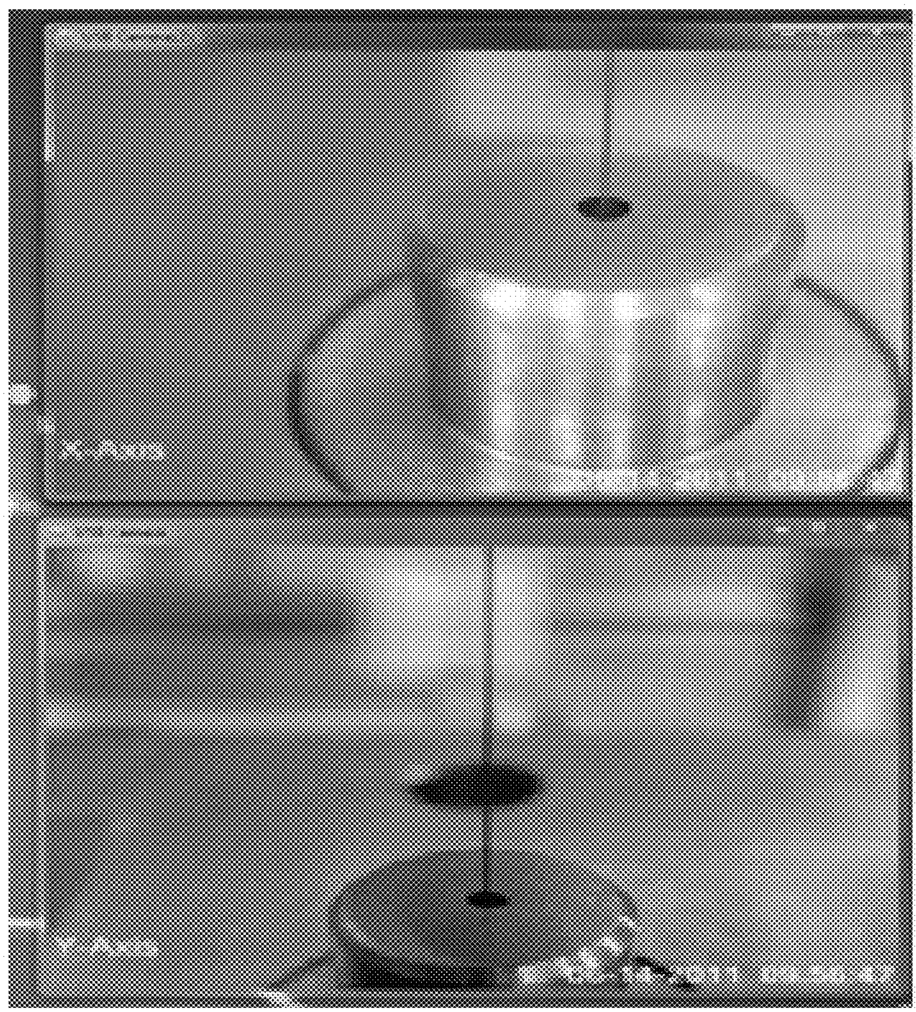


Figure 4

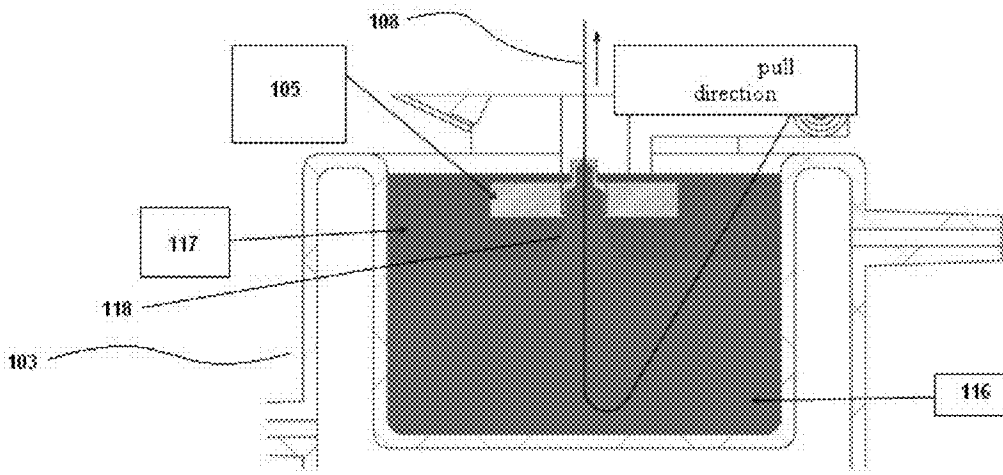


Figure 5

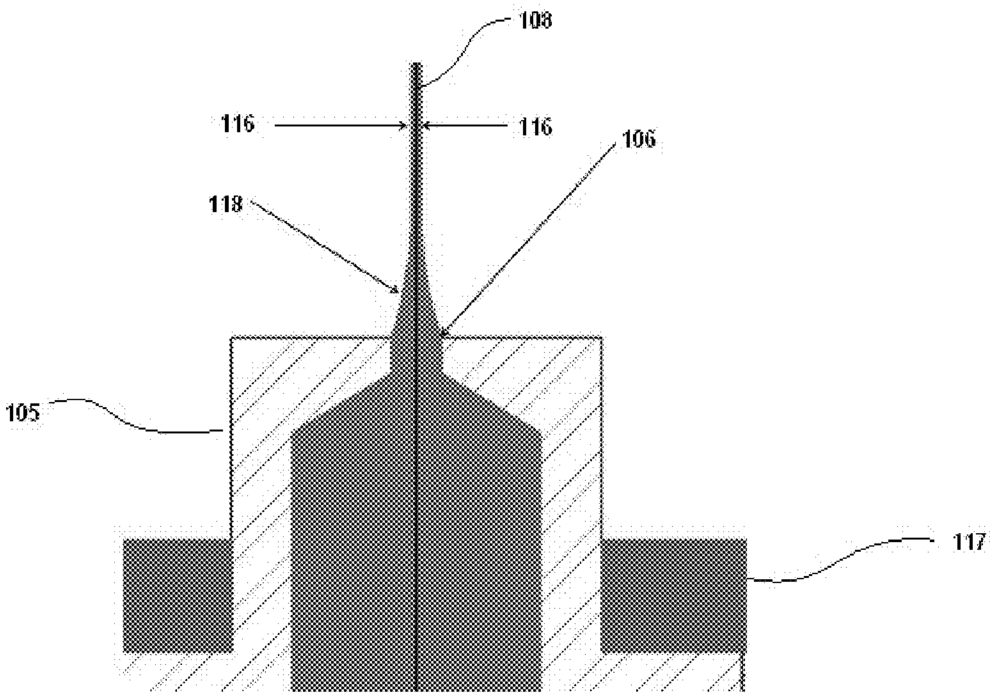
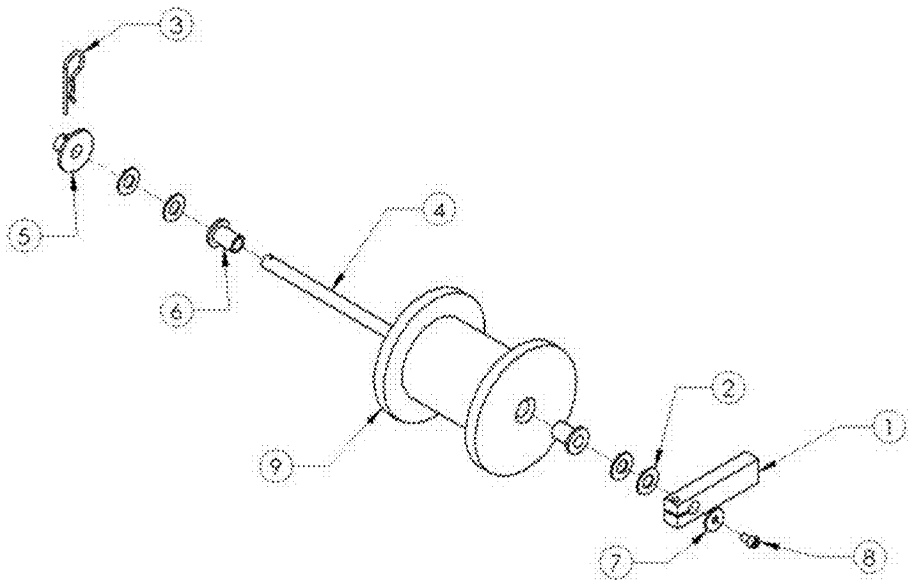


Figure 6



ITEM NO.	QTY	PART NUMBER	DESCRIPTION
1	1	4110-003	COEXTRUSION SPOOL MOUNT
2	4	6046-001	TEFLON THRUST BEARING
3	1	6045-001	HAIRPIN COTTER PIN
4	1	4125-001	SPOOL AXLE
5	1	4126-001	BOBBIN RETAINER
6	2	4121-001	BOBBIN FLANGE BUSHING
7	1	N/A	WASHER, M6 OVERSIZED SS
8	1	N/A	SHCS M6 X 10 SS
9	1	N/A	MANDREL SPOOL

Figure 7

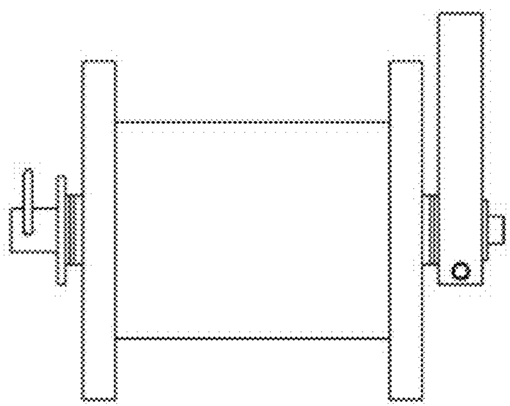


Figure 8

SYSTEMS AND METHODS FOR MAKING GELATIN SHUNTS

FIELD OF THE INVENTION

[0001] The invention generally relates to systems and methods for making gelatin shunts.

BACKGROUND

[0002] Glaucoma is a disease of the eye that affects millions of people. Glaucoma is associated with an increase in intraocular pressure resulting either from a failure of a drainage system of an eye to adequately remove aqueous humor from an anterior chamber of the eye or overproduction of aqueous humor by a ciliary body in the eye. Build-up of aqueous humor and resulting intraocular pressure may result in irreversible damage to the optic nerve and the retina, which may lead to irreversible retinal damage and blindness.

[0003] Glaucoma may be treated in a number of different ways. One manner of treatment involves delivery of drugs such as beta-blockers or prostaglandins to the eye to either reduce production of aqueous humor or increase flow of aqueous humor from an anterior chamber of the eye. Glaucoma may also be treated by surgical intervention that involves placing a shunt in the eye to result in production of fluid flow pathways between an anterior chamber of an eye and various structures of the eye involved in aqueous humor drainage (e.g., Schlemm's canal, the sclera, or the subconjunctival space). Such fluid flow pathways allow for aqueous humor to exit the anterior chamber.

[0004] A problem with implantable shunts is that they are composed of a rigid material, e.g., stainless steel, that does not allow the shunt to react to movement of tissue surrounding the eye. Consequently, existing shunts have a tendency to move after implantation, affecting ability of the shunt to conduct fluid away from the anterior chamber of the eye. To prevent movement of the shunt after implantation, certain shunts are held in place in the eye by an anchor that extends from a body of the shunt and interacts with the surrounding tissue. Such anchors result in irritation and inflammation of the surrounding tissue. Further, implanting a rigid shunt may result in the shunt causing blunt trauma upon insertion into an eye, such as producing a cyclodialysis cleft, or separation of the ciliary body from the scleral spur, creating hypotony by allowing the uncontrolled escape of aqueous humor through the cleft into the suprachoroidal space.

[0005] To address the problems associated with shunts made of rigid material, people have begun to make shunts from flexible material, such as gelatin. See for example, Yu et al. (U.S. Pat. No. 6,544,249 and U.S. patent application publication number 2008/0108933). Gelatin shunts may be reactive to pressure, and thus can be implanted without the use of anchors. Consequently, gelatin shunts will maintain fluid flow away for an anterior chamber of the eye after implantation without causing irritation or inflammation to the tissue surrounding the eye. Additionally, the flexibility of a gelatin shunt prevents it from causing blunt trauma upon insertion into an eye, and thus reduces or eliminates the risk of producing a cyclodialysis cleft.

[0006] However, there are numerous issues associated with making gelatin shunts. For example, it is difficult to control and manipulate liquid gelatin, which is important in order to produce a gelatin shunt with a uniform cross-section and uniform shape along a length of the implant. Additionally, there are challenges associated with the drying process that also make it difficult to produce a gelatin shunt with a uniform cross-section and uniform shape along a length of the implant.

SUMMARY

[0007] The invention generally provides systems and methods for making gelatin shunts. Particularly, systems and methods of the invention address and solve the above described problems with manufacturing gelatin shunts.

[0008] Certain aspects of the invention address the problems of controlling and manipulating liquid gelatin. The invention recognizes that simply routing a wire through a temperature controlled gelatin bath is not sufficient to produce a gelatin shunt with a uniform cross-section and uniform shape along a length of the implant. Heated gelatin alone forms a skin layer on top of the gelatin. Pulling a wire through a gelatin bath alone results in the wire passing through the skin layer, which makes it impractical to control the gelatin uptake on the wire. The invention solves this aspect of the problem by adding a water layer on top of the gelatin. The water layer eliminates the skin effect, and allows for production of a uniform cone of gelatin upon pulling a wire through the gelatin and then the water layer. Where the gelatin cone intersects the water-air boundary, a spot forms. This spot is exposed to air, and gelatin from this spot is taken up the wire.

[0009] However, the invention also recognizes that more gelatin reaches the top of the water than can be taken up by the wire. This results in cast-off, which renders the cone, and thus the spot at the boundary layer, unstable, i.e., the gelatin deposit is inconsistent in diameter. To solve this aspect of the problem, the systems and methods of the invention use a plate having an aperture, which aperture controls the gelatin spot. The plate having the aperture is situated in the water layer, and with the aperture plate in place, the cone of gelatin that feeds the spot is consistent and yields a uniform uptake of gelatin onto the wire.

[0010] Other aspects of the invention address the problems associated with the drying process that also make it difficult to produce a gelatin shunt with a uniform cross-section and uniform shape along a length of the implant. As the water evaporates from the gelatin on the wire, the gelatin shrinks in diameter. However, the wire constrains the gelatin from shrinking axially. If humidity is left uncontrolled, an outer skin of the gelatin dries and hardens before the gelatin has completed shrinking. This results in non uniform cross sections and shapes along the implant length. The invention recognizes that drying the gelatin on the wire in a humidity controlled space produces a uniform implant along the length of the wire. One manner by which this is accomplished involves immersing the gelatin in an ultrasonic fog that keeps the outer skin of the gelatin hydrated as the internal volume of the gelatin shrinks.

[0011] Systems and methods of the invention incorporate these solutions to the above described problems associated with manufacturing a gelatin shunt. Methods of the invention may involve moving a wire through a bath including a bottom layer of liquid gelatin and a top layer of water, thereby coating the wire with gelatin, moving the gelatin coated wire through an aperture, and drying the gelatin on the wire in a humidity controlled space, thereby manufacturing a gelatin shunt. The dried shunt includes a uniform shape and a uniform cross-section.

[0012] Movement of the wire may be controlled manually or mechanically. In certain embodiments, the moving wire is mechanically controlled, by for example, by a stepper motor.

[0013] Any method for controlling humidity may be used with methods of the invention. In particular embodiments, the humidity is controlled by drying in the presence of an ultrasonic water fog. The aperture is generally located in the water layer, and the wire is preferably moved vertically through the bath, such that the gelatin coated wire is vertical during the drying step. In certain embodiments, the manufactured shunt is sized and dimensioned to be an intraocular shunt.

[0014] In certain embodiments, the liquid gelatin may include a drug, and thus produces shunts that may be coated or impregnated with at least one pharmaceutical and/or biological agent or a combination thereof. Any pharmaceutical and/or biological agent or combination thereof may be used with shunts of the invention. The pharmaceutical and/or biological agent may be released over a short period of time (e.g., seconds) or may be released over longer periods of time (e.g., days, weeks, months, or even years). Exemplary agents include anti-mitotic pharmaceuticals such as Mitomycin-C or **5**-Fluorouracil, anti-VEGF (such as Lucintes, Macugen, Avastin, VEGF or steroids). Exemplary agents are shown in Darouiche (U.S. Pat. Nos. 7,790,183; 6,719,991; 6,558,686; 6,162,487; 5,902,283; 5,853,745; and 5,624,704) and Yu et al. (U.S. patent application serial number 2008/0108933). The content of each of these references is incorporated by reference herein its entirety.

[0015] Systems of the invention may include a motor, a wire operably coupled to the motor for movement of the wire, a temperature controllable bath, an aperture plate situated in a top portion of the bath, and an ultrasonic fogger, the system being configured such that the wire moves through the bath, through the aperture plate, and into the ultrasonic fogger. Generally, the wire initially moves down toward a bottom of the bath and then turns to move vertically out of the bath. From there, the wire moves through the aperture plate, and then the wire moves vertically through the ultrasonic fogger.

[0016] Systems of the invention may also include a first camera positioned to view the wire as it moves through the aperture plate. Systems of the invention may also further include a second camera that includes software to measure the gelatin coated wire as it passes into the fogger.

[0017] The bath may be filled with liquid gelatin and water. The liquid gelatin fills a bottom layer of the bath and the water fills a top layer of bath. In certain embodiments, the liquid gelatin includes a drug.

BRIEF DESCRIPTION OF THE DRAWINGS

[0018] FIG. **1** is a schematic shows an embodiment of a system of the invention.

[0019] FIG. **2** is a schematic showing a magnified view of FIG. **1**, focusing on the wheels that carry the wire.

[0020] FIG. **3** is an image of the aperture plate with a wire running through the aperture.

[0021] FIG. **4** shows the images captured by the first and second camera as the wire emerges from the aperture in the aperture plate.

[0022] FIG. **5** is a schematic showing the wire being pulled through the gelatin and water layers and through the aperture in the aperture plate.

[0023] FIG. **6** is a schematic showing a magnified view of a gelatin cone interacting with the aperture plate as the wire moves through the aperture plate.

[0024] FIG. **7** is a schematic showing an exploded view of a spool.

[0025] FIG. **8** is a schematic showing the final assembled spool.

DETAILED DESCRIPTION

[0026] FIG. **1** shows an embodiment of a system **100** of the invention for manufacturing a gelatin shunt. Device **100** includes a base **101** and a vertically extending shaft **102**. There is a bath **103** at an the junction of the base **101** and the shaft **102**, such that the shaft **102** is aligned with the bath **103**. The bath **103** can be any vessel configured to hold a liquid. In systems of the invention, the bath **103** holds the liquid gelatin and the water. The bath is operably connected to a temperature control unit **104**. The temperature control unit **104** regulates the temperature of the bath **103**, and any liquids within the bath **103**. For making a shunt, the bath is maintained at about 55° C.

[0027] In particular embodiments, the bath **103** is a jacketed flask and the temperature control unit **104** is a water circulator with a heating component. The heater of the temperature control unit is set to a particular temperature, for example 55° C., which heats the water in the water circulator to the set temperature. The heated water is then circulated by the water circulator to the jacked flask, which heats the flask, and its contents, to the temperature defined by the temperature control unit. Generally, the water level in the jacketed flask will be above the level of the gelatin inside the flask.

[0028] To the top of the bath **103** is affixed an aperture plate **105**, i.e., a plate having an aperture **106** therethrough. The plate **105** is affixed to the bath **103** such that the aperture **106** is aligned with the shaft **102**. An exemplary shaped aperture plate **105** is shown in FIG. **3**. In this figure, the plate **105** has a base portion and a protruding portion affixed to the base. The aperture runs through the base and through the protruding portion.

[0029] System **100** includes a plurality of wheels **107**. The wheels **107** support a wire **108** and are arranged in a path that the wire **108** will travel. FIG. **2** is a magnified view of the system **100** shown in FIG. **1**. FIG. **2** better shows the positioning of wheels **107** and the path of travel of wire **108**. Wheel **107***a* is mounted approximately half way up the shaft **102**. The exact position of wheel **107***a* on shaft **102** is not important and other positions of wheel **107***a* are envisioned for the systems of the invention. Wheel **107***b* is mounted on a support near the base **101** and is positioned to be directly below wheel **107***a*. Although, such exact positioning is not critical and wheel **107***b* may be placed in other places along the base. Wheel **107***c* is mounted at a top right edge of the bath **103**. Wheel **107***d* is mounted at a bottom of bath **103**. Wheel **107***d* is mounted such that it is in alignment with aperture **106** of aperture plate **105** and shaft **102**. Wheel **107***e* is positioned at the top of shaft **102**. The exact position of wheel **107***e* on shaft **102** is not important and other positions of wheel **107***e* are envisioned for the systems of the invention. Wheel **107***f* is mounted on a support near the base **101**. Wheel **107***f* is operably coupled to stepper motor **109**. An exemplary stepper motor is commercially available from Automation Direct (Cumming, Ga.).

[0030] The wheels **107** are arranged such that when wire **108** is mounted on wheels **107**, the wheels provide a constant tension for wire **108**. Wire **108** is spooled on wheel **107***a*. Wire **108** is then run under wheel **107***b*, over wheel **107***c*, under wheel **107***d*, over wheel **107***e*, and spools again onto wheel **107***f*. The arrangement provides that wire **108** travels down into the base of bath **103**, and makes a turn at the base of bath **103**, such that after the turn, wire **108** travels vertically up through the bath **103**, through the aperture **106** of the aperture plate **105**, and vertically up the length of the shaft **102** to wheel **107***e*.

[0031] Stepper motor **109** in connection with wheel **107***f* drives movement of wire **108** and controls the speed at which wire **108** travels. The thickness of the walls of the formed shunt will depend on the speed at which the wire **108** is traveling. Increasing the pull speed will increase the diameter of the shunt, while decreasing the pull speed will decrease the diameter of the shunt. Stepper motor **109** is controlled by computer **114** and powered by DC power supply **115**.

[0032] Wire **108** is preferably stainless steel, which may optionally be coated with a biocompatible, lubricious material such as polytetrafluoroethylene (Teflon). The coating helps in removing the dried gelatin shunt from the wire **108**. The gauge of the wire will depend on the desired inner diameter of the shunt being produced. Generally, wires are used that produce a shunt having an inner diameter from approximately 10 μm to approximately 250 μm, preferably from about 40 μm to about 200 μm.

[0033] System **100** may include at least one camera for real time monitoring of the manufacturing of the shunt. FIGS. **1-2** show an embodiment that includes two cameras **110** and **111**. Camera **110** monitors the wire **108** at the point that it is emerging from the aperture **106**. Camera **111** is a high magnification camera that includes measurement software to allow for real time measurement of the thickness and diameter of the gelatin coating the wire **108** as it emerges from the aperture **106**. Exemplary cameras are DINO-LITE cameras, commercially available from (AnMo Electronics Corporation, Torrance, Calif.). FIG. **4** shows the images captured by cameras **110** and **111**. The top image, is the image produced by camera **111**, and the bottom image is the image produced by camera **110**). Cameras **110** and **111** are operably coupled to computer **114**, which controls the cameras.

[0034] System **100** also includes an ultrasonic fogger **112** coupled to a tube **113**. The tube **113** runs most of the length of the shaft **102**, extending from the top of the shaft **102** down to the top camera **111**. The tube **113** is positioned such that the wire **108** pass into the tube **113** upon emerging from the aperture **106**. The fogger **112** is positioned such that the produced fog enters the tube **113**. The fog produced by the fogger **112** keeps the outer skin of the gelatin hydrated as the internal volume of the gelatin shrinks. An exemplary fogger is commercially available from Exo-terra (Mansfield, Mass.).

[0035] To make the gelatin shunt, the bath **103** is pre-heated to a temperature of about 55° C. During the pre-heating, the liquid gelatin **116** is made. In a certain embodiment, the gelatin used for making the shunt is known as gelatin Type B from bovine skin. An exemplary gelatin is PB Leiner gelatin from bovine skin, Type B, 225 Bloom, USP. Another material that may be used in the making of the shunt is a gelatin Type A from porcine skin, also available from Sigma Chemical. Such gelatin is available from Sigma Chemical Company of St. Louis, Mo. under Code G-9382. Still other suitable gelatins include bovine bone gelatin, porcine bone gelatin and human-derived gelatins. In addition to gelatins, the flexible portion may be made of hydroxypropyl methycellulose (HPMC), collagen, polylactic acid, polylglycolic acid, hyaluronic acid and glycosaminoglycans.

[0036] In an exemplary protocol, the gelatin solution is typically prepared by dissolving a gelatin powder in de-ionized water or sterile water for injection and placing the dissolved gelatin in a water bath at a temperature of approximately 55° C. with thorough mixing to ensure complete dissolution of the gelatin. In one embodiment, the ratio of solid gelatin to water is approximately 10% to 50% gelatin by weight to 50% to 90% by weight of water. In an embodiment, the gelatin solution includes approximately 40% by weight, gelatin dissolved in water. The resulting gelatin solution should be devoid of air bubbles and has a viscosity that is between approximately 200-500 cp and more particularly between approximately 260 and 410 cp (centipoise).

[0037] FIGS. **5** and **6** illustrate the process of the gelatin **116** being taken up the wire **108**. Once prepared, the liquid gelatin **116** is poured into bath **103** that has been pre-heated to 55° C., thus maintaining the liquid gelatin at 55° C. After the gelatin **116** has been poured into the bath **103**, a water layer **117** is added on top of the gelatin layer **116**. The water envelops the aperture plate **105** such that a top surface of the plate **105** is submerged about 1 mm below the surface of water **117**. The bottom of the plate **105** is positioned so that it does not touch the gelatin layer **116**. Powered by stepper motor **109**, the wire **108** is pulled down into the base of the bath **103** and then turns vertically up through the gelatin layer **116**, the water layer **117**, and the aperture **106** in the aperture plate **105**. In this manner, the wire **108** becomes coated with gelatin **116** as it passes through the gelatin layer **116**. Upon pulling the gelatin **116** through the water layer **117**, a uniform cone **118** of gelatin **116** forms. Where the cone **118** intersects the water-air boundary, a spot forms. The cone **118** feeds into the aperture **106** in the aperture plate **105**. The aperture **106** controls the gelatin **116** and the spot, such that the cone **118** of gelatin **116** that feeds the spot is consistent and yields a uniform uptake of gelatin **116** onto the wire **108**.

[0038] The wire **108** then advances past cameras **110** and **111**, which provide a real-time check of the thickness of the gelatin **116** that is being taken up the wire **108**. Feedback from the camera can be used to adjust the speed of the wire **108**, thus adjusting the thickness of the gelatin **116**. Increasing the pull speed will increase the diameter of the shunt, while decreasing the pull speed will decrease the diameter of the shunt.

[0039] After passing the cameras, the gelatin coated wire moves into tube **113** that is already being supplied with fog from fogger **112**. The wire **108** is advanced until the wet gelatin **116** reaches the wheel **107***e* at the top of the shaft **102**. The gelatin **116** on the wire **108** becomes immersed in the fog from fogger **112**. The fogger is run for approximately 5-10 minutes after the gelatin coated wire enters the fogger. The fogger is turned off and the gelatin is allowed to dry. Having the outer skin of the gelatin **116** in a humidity controlled environment, keeps the skin of the gelatin **116** hydrated as an internal volume of the gelatin **116** shrinks. In this manner, a uniform implant is produced along the length of the wire **108**.

[0040] The wire **108** is then cut below wheel **107***e* and above the top camera **111**, using for example, stainless steel surgical sheers. The wire is cut into sections using the stainless steel surgical sheers to produce sections of a desired length. At this point, a cross-linking procedure can be performed on the gelatin. In one embodiment, the gelatin may be cross-linked by dipping the wire sections (with gelatin thereon) into the 25% glutaraldehyde solution, at pH of approximately 7.0-7.8 and more preferably approximately

7.35-7.44 at room temperature for at least 4 hours and preferably between approximately 10 to 36 hours, depending on the degree of cross-linking desired. In one embodiment, the gelatin is contacted with a cross-linking agent such as gluteraldehyde for at least approximately 16 hours. Cross-linking can also be accelerated when it is performed a high temperatures. It is believed that the degree of cross-linking is proportional to the bioabsorption time of the shunt once implanted. In general, the more cross-linking, the longer the survival of the shunt in the body.

[0041] The residual glutaraldehyde or other cross-linking agent is removed from the gelatin by soaking the tubes in a volume of sterile water for injection. The water may optionally be replaced at regular intervals, circulated or re-circulated to accelerate diffusion of the unbound glutaraldehyde from the gelatin. The gelatin is washed for a period of a few hours to a period of a few months with the ideal time being 3-14 days. The now cross-linked gelatin may then be dried (cured) at ambient temperature for a selected period of time. It has been observed that a drying period of approximately 48-96 hours and more typically 3 days (i.e., 72 hours) may be preferred for the formation of the cross-linked gelatin.

[0042] Where a cross-linking agent is used, it may be desirable to include a quenching agent. Quenching agents remove unbound molecules of the cross-linking agent from the gelatin. In certain cases, removing the cross-linking agent may reduce the potential toxicity to a patient if too much of the cross-linking agent is released from the gelatin. In certain embodiments, the gelatin is contacted with the quenching agent after the cross-linking treatment and, may be included with the washing/rinsing solution. Examples of quenching agents include glycine or sodium borohydride.

[0043] In certain embodiments, drug coated/drug impregnated shunts are produced. Shunts may be coated or impregnated with at least one pharmaceutical and/or biological agent or a combination thereof. Any pharmaceutical and/or biological agent or combination thereof may be used with shunts of the invention. The pharmaceutical and/or biological agent may be released over a short period of time (e.g., seconds) or may be released over longer periods of time (e.g., days, weeks, months, or even years). Exemplary agents include anti-mitotic pharmaceuticals such as Mitomycin-C or 5-Fluorouracil, anti-VEGF (such as Lucintes, Macugen, Avastin, VEGF or steroids). Exemplary agents are shown in Darouiche (U.S. Pat. Nos. 7,790,183; 6,719,991; 6,558,686; 6,162,487; 5,902,283; 5,853,745; and 5,624,704) and Yu et al. (U.S. patent application serial number 2008/0108933). The content of each of these references is incorporated by reference herein its entirety.

[0044] In certain embodiments, an implant is produced with a thin layer of drug infused gelatin on an inside of the shunt. The thin inner layer will dissolve over time, thus delivering the drug.

[0045] To produce such a shunt, the wire is pulled through a gelatin solution that has been infused with a drug to deposit a thin wall (e.g., 3-20 μm) of drug-infused gelatin on the wire. Alternatively, the wire is pulled through a gelatin solution that does not include a drug and the gelatin is instead soaked in the drug after it is pulled on the wire. In either case, the drug infused gelatin is then subjected to crosslinking with a controlled glutaraldehyde concentration for a controlled time to effect a non-permanent crosslinking that dissolves over time in tissue. Once this drug infused gelatin has been produced, the drug-infused gelatin is then pulled through the standard gelatin bath to coat the drug infused gelatin with a layer of gelatin that does not include a drug. This produces he final diameter of the shunt. The drug free layer of gelatin is then permanently crosslinked, thus producing a shunt with a thin layer of drug infused gelatin on an inside of the shunt.

[0046] In other embodiments, an implant is produced with a thin layer of drug infused gelatin on an outside of the shunt. The thin inner layer will dissolve over time, thus delivering the drug. To produce such a shunt, the wire is pulled through the standard gelatin solution in the bath to a diameter of about 3-50 the wire is pulled through the standard gelatin solution in the bath to a diameter of about 3-50 μm smaller than the desired diameter of the final implant. This layer is permanently crosslinked. The gelatin coated wire is then pulled through a drug infused gelatin solution to deposit a thin wall (e.g., 3-50 μm) onto the gelatin coated wire. Alternatively, the wire is pulled through a gelatin solution that does not include a drug and the gelatin is instead soaked in the drug after it is pulled on the wire. In either case, the drug infused gelatin is then subjected to crosslinking with a controlled glutaraldehyde concentration for a controlled time to effect a non-permanent crosslinking that dissolves over time in tissue.

Incorporation by Reference

[0047] References and citations to other documents, such as patents, patent applications, patent publications, journals, books, papers, web contents, have been made throughout this disclosure. All such documents are hereby incorporated herein by reference in their entirety for all purposes.

Equivalents

[0048] The invention may be embodied in other specific forms without departing from the spirit or essential characteristics thereof. The foregoing embodiments are therefore to be considered in all respects illustrative rather than limiting on the invention described herein. Scope of the invention is thus indicated by the appended claims rather than by the foregoing description, and all changes which come within the meaning and range of equivalency of the claims are therefore intended to be embraced therein.

EXAMPLES

Example 1

Gelatin Preparation

[0049] Into a 600 mL beaker was added 98±1 grams of porcine gelatin. An amount of about 172±1 grams of USP sterile water was measured and poured into the beaker containing the porcine gelatin. The beaker was sealed with parafilm, and the covered beaker was placed in a water bath at 55±1° C. for a minimum of 8 hours (maximum 36 hours). Ensure water level is higher than mixture in beaker. The lid of the water bath was checked to ensure that it was closed and after the minimum time period had elapsed, the beaker was removed from bath. The beaker was visually observed to verify that all gelatin in the mixture was dissolved and that mixture appeared homogeneous.

Example 2

Gelatin Transfer

[0050] The water circulator was checked to make sure that it was at a sufficient level (between the high and low marks).

The circulator was set and run at 40.5° C. and allowed to come to temperature before proceeding to the next step. The gelatin mixture from Example 1 was poured into the jacketed beaker on a fixture so that the meniscus was about 20 mm from the top. Within 1 minute of adding the gelatin mixture, 60 cc's of USP sterile water was added above the gelatin surface using a syringe. The water was added slowly so as not to disturb the gelatin. The mixture was allowed to settle for minimum 30 min.

Example 3

System Set-Up

[0051] A spool was assembled onto an axle using parts as shown in FIG. **7**. The final assembled spool is shown in FIG. **8**. The M6 screw (Item **8**) was finger tightened, and pinch bolt (Item **7**) was fastened onto the mount. In order to increase the friction on the spool, the M6 screw (Item **8**) was advanced approximately a ¼ turn. The wire was then threaded onto the spool, and the spool was slid up the shaft. The spindle assembly was lowered into the gelatin mixture, about 5 mm from the bottom of flask. The aperture plate was lowered into the water layer under a top surface was submerged about 1 mm below the surface of water. The bottom surface of the aperture plate was above the gelatin layer.

[0052] The first and second cameras were positioned on the shaft so as to properly view the wire as it emerged from the aperture in the aperture plate. The tube of the fogger assembly was lowered over the shaft until a bottom of the tube is positioned just above the second camera. In this position, a top of the tube was approximately 2 inches above the upper wheel on the shaft. The fogger was started, and the volume and velocity on the fogger was adjusted until the fog was barely visible flowing at the bottom of the tube. The computer was initiated and the images produced by the camera were checked to ensure proper positioning of the cameras. The cameras were focused until edges of the wire had sharp contrast.

Example 4

Shunt Manufacturing

[0053] The computer was used to initiate the stepper motor and begin pulling the wire. The initial pull speed was 8,000 rpm. The aperture was checked for dry gelatin, and any dried gelatin was cleared by grasping the wire above the top camera using a gloved hand and swirling the wire around lightly for a few seconds while monitoring the aperture cameras. The concentration of the gelatin on the wire was fine tuned by monitoring the cameras. Turning the X-axis stage micrometer in the clockwise direction moved the wire to the right relative to the gelatin. Turning the Y-axis stage micrometer in the clockwise direction moved the wire to the left relative to the gelatin. Active measures of the gelatin thickness on the wire were taken. The total diameter of the gelatin in both the X and Y views was measured. The relative wall thickness of the gelatin on each side of the wire in both the X and Y views was obtained by measuring from the left edge of the gelatin to the left edge of the wire and from the right edge of the gelatin to the right edge of the wire. The pull speed was adjusted to achieve a target wet diameter of the gelatin.

[0054] Once the target wet diameter was achieved, the fixture was run until gelatin reached the upper wheel at the top of the shaft. The movement of the wire was stopped at this point. After terminating the movement of the wire, the fog from the fogger was allowed to continue to flow over the wire for a minimum of 5 additional minutes. After five minutes, the fogger was turned off and the gelatin was allowed to dry for a minimum of 3 additional minutes. The wire was then cut below the upper wheel and above the top camera using stainless steel surgical shears. The cut wire was then subsequently cut into 4-4.25 inch sections using stainless steel surgical shears and prepared for crosslinking. The individual sections were crosslinked. The shunts were then cut to a desired length (e.g., 2-20 mm), and each shunt was removed from the wire.

What is claimed is:

1. A method for manufacturing a gelatin shunt, the method comprising:

moving a wire through a bath comprising a bottom layer of liquid gelatin and a top layer of water, thereby coating the wire with gelatin;

moving the gelatin coated wire through an aperture; and

drying the gelatin on the wire in a humidity controlled space, thereby manufacturing a gelatin shunt.

2. The method according to claim **1**, wherein the dried shunt comprises a uniform shape and a uniform cross-section.

3. The method according to claim **1**, wherein the liquid gelatin comprises a drug.

4. The method according to claim **1**, wherein the moving wire is mechanically controlled.

5. The method according to claim **1**, wherein the humidity is controlled by drying in the presence of an ultrasonic water fog.

6. The method according to claim **1**, wherein the aperture is in the water layer.

7. The method according to claim **1**, wherein the wire is moved vertically through the bath.

8. The method according to claim **1**, wherein the gelatin coated wire is vertical during the drying step.

9. The method according to claim **1**, wherein the manufactured shunt is sized and dimensioned to be an intraocular shunt.

10. A system for manufacturing a gelatin shunt, the system comprising:

a motor;

a wire operably coupled to the motor for movement of the wire;

a temperature controllable bath;

an aperture plate situated in a top portion of the bath; and

an ultrasonic fogger;

wherein the system is configured such that the wire moves through the bath, through the aperture plate, and into the ultrasonic fogger.

11. The system according to claim **10**, wherein the wire initially moves down toward a bottom of the bath and then turns to move vertically out of the bath.

12. The system according to claim **11**, wherein the wire moves through the aperture plate.

13. The system according to claim **12**, wherein the wire moves vertically through the ultrasonic fogger.

14. The system according to claim **13**, further comprising a first camera positioned to view the wire as it moves through the aperture plate.

15. The system according to claim **14**, further comprising a second camera that comprises software to measure the gelatin coated wire as it passes into the fogger.

16. The system according to claim **15**, further comprising liquid gelatin filling a bottom layer of the bath and water filling a top layer of bath.

17. The system according to claim **16**, wherein the liquid gelatin comprises a drug.

18. The system according to claim **10**, wherein the shunt is an intraocular shunt.

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